

# Soil Quality Improves Slowly

## *A Scientific Look at Improving Soil Structure*

### To Till or Not to Till

Inversion tillage has a detrimental effect of tumbling the soil which creates an explosion affect which will shatter, split, tear, and rip soil structural units apart and into less defined smaller segments (*Figure 2*). Yes this may bring in more O<sub>2</sub> and CO<sub>2</sub> into the soil for a very short period



Figure 1. Poor structure

but this severe manipulation causes a quick breakdown of carbon stored and oxygen stored, to be released into the atmosphere. The tumbling effect breaks soil structure on different and irregular fracture planes that which are not natural.



Figure 2. Tumbling soil via plow

As this occurs soil loses its inherent capacity to reform by natural gravitational forces, along with expansion, and contraction forces with soil clay's complex structure and bonding forms. With long periods of rest when not being tilled, the soil matrix will have an opportunity to reform into specific structural units. Tillage events will continue to break down soil structure into a condition of disarray where the soil melts together into something akin to concrete-like structure due to excess tillage.

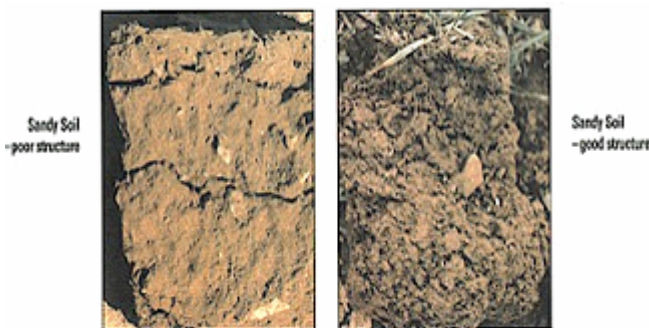


Figure 3. Poor soil structure (on left), very well aggregated structure on the right

---

***" When soil is overused and tells us it is damaged - it needs a softer touch."***

---

As years go by and the soil is continued to be rearranged by disruptive events of tillage, the soil has little or no chance to naturally form into prismatic, columnar or blocky forms. Water entering into the soil has to go through a tortuous route to seep into deeper sections of the soil profile.

### Rebuilding Healthy Soils

As surface and near-surface soils are allowed to reform under natural phenomena in no-till type tillage systems, soil quality does improve. Five of those phenomena are: **1)** freeze-thaw action in the geographic regions that have long periods of below freezing, during these periods ice-crystals form, melt and reform orienting soil particles along the cleavage planes of the ice crystals (*Figure 4*), **2)** gravitational settling, larger and heavier particles settling out first (sand sized)

then silts and last clays, **3)** water movement by gravity cohesively and adhesively pulling clays and silts downward, as this occurs clay will create a film like a glue to hold soil particles together in vertical shaped forms, **4)** shrink-swell forces, clay is in leaf upon leaf-like structures, these structures are held by chemical bonds of silicon, hydrogen and oxygen, as water is introduced the O and H bonds are spread apart causing soils to swell. As drying occurs by soil heat transfer or roots absorbing water the clay lattice structure may fail, clogging could occur of soil pores and cracks. **5)** As fewer and fewer tillage passes allow rest to the friendly soil fungi spores and growth for symbiotic relationship with plant roots.



Figure 4. Ice crystals in soils

These fungi live in the upper 15 to 25 cm (6 to 12 inches) and develop fine hair-like structures (hyphae) that extend from the root up to 10 cm (4 inches) long out into the soil. These hyphae appear like a spider web in and between soil particles (see *Figure 5*). These hyphae exude or give off a sticky substance that helps glue soil particles together – this material is called “glomalin”. Mycorrhizal fungi absorb phosphorus, organic nitrogen, very small quantities of zinc and sulfur and feed their hosts in exchange for plant sugars. Nearly all higher plants co-exist with mycorrhizal fungi and depend upon that relationship. In high ‘P’ soil tests and highly active shrink-swell clays and organic soils, mycorrhizal fungi have less effect to plants.



Figure 5. Close-up of VAM fungi hyphae

## Importance of Biochemical Actions

The effectiveness of soil carbon in forming stable aggregates is partly related to its decomposition rate, which in turn is influenced by its physical and chemical protection from microbial action. The precipitation of (hydr)oxides, phosphates and carbonates can enhance aggregation (Bronick and Lal, 2005). Roots and hyphae will link particles together all the while realigning them and releasing organic compounds that hold particles together. This can be a process with a positive impact on soil C sequestration. Plant roots can exert compactive stresses on surrounding soil material. Exudates from mucigels will remain in soil matrix which promote structure formation (Elliott and Coleman, 1988). Best farming practices that increase productivity and decrease soil disruption or tillage will enhance soil aggregation, soil quality, and structural development.

Biological processes do exert a particularly strong influence on formation of structure in surface horizons. The incorporation of soil organic matter is usually greatest in surface horizons. Soil organic matter serves as an agent for building soil aggregates, particularly the polysaccharides appear to be responsible for the formation of peds. Soil-dwelling animals (e.g., earth worms,



gophers) also exert compactive forces like that of roots, and in some cases (e.g., earth worms) further contribute to structure formation via ingestion/excretion of soil material that includes incorporated organic secretions. To give a picture of the interaction with the biota, fungal growth, and issues with clay and organic matter look at *Figure 6* below from Hunt et al. 2002.

As soil quality improves it has been observed that soil structure within a seven year period will change to a more stable grade – from weak to moderate to strong structure. Researchers in eastern Colorado have observed in a long term strip-till study that with more lateral tillage soil porosity decreases. The number of macropores and micropores decrease by 35-40% in conventional till plots compared to multiple years of No-till. This process of building structure is slow unless more and more compound polysaccharides are left in the soil matrix as well as cellulose and lignin materials. Long lasting carbon compounds from degenerating roots and fungi hyphae are slow to accumulate from fine rooted crops such as small grains. Tisdall and Oades (1982) have put together a model that better describes how soils aggregate. First they state, amorphous organics attach to the clay particles, and then microbial debris encrusts those particles so they can bind together.

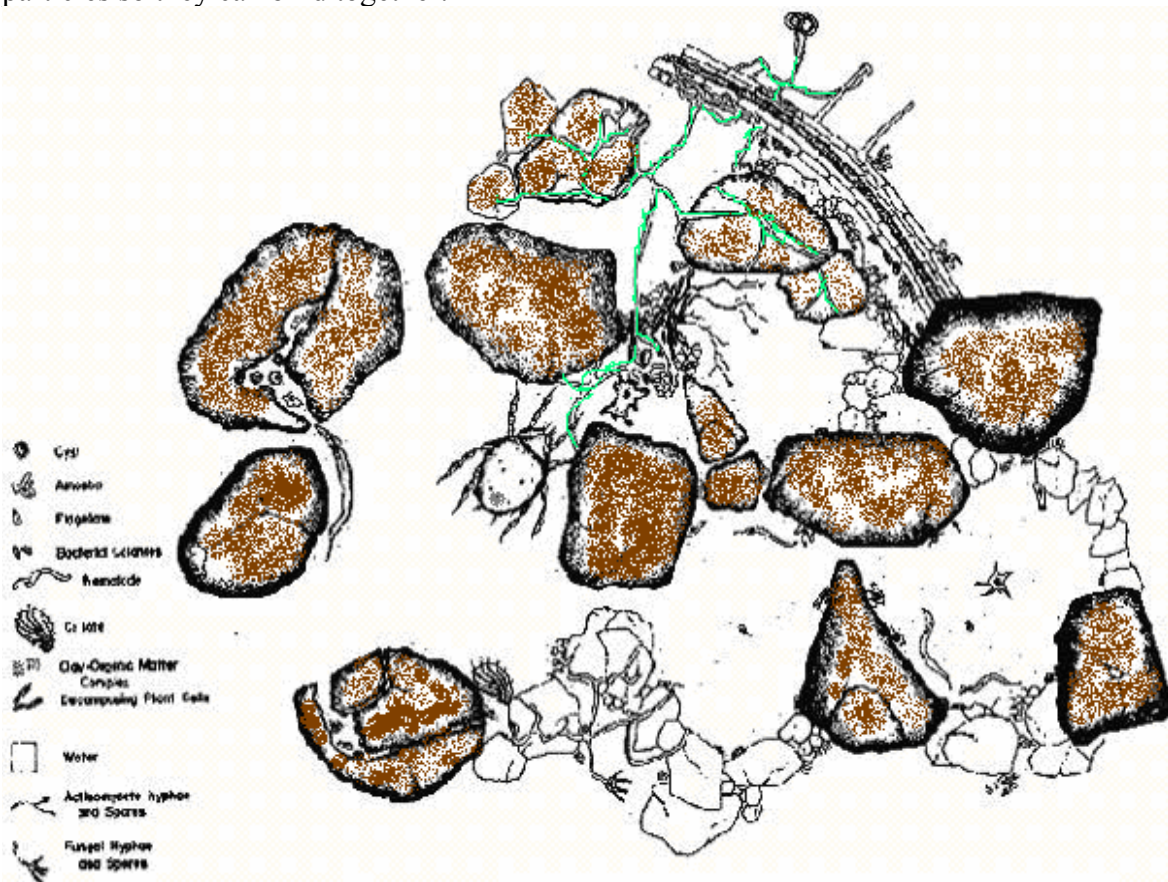


Figure 6. Horizontal cross section (1cm<sup>2</sup>) of a highly structured and biologically active microsite in the short grass prairie. It depicts how different classes of pore space and distribution of water within pores influence the feeding and the habitat relationships among the different groups of soil organisms. Illustration by S.L. Rose

This occurs with other primary soil particles (sand, silt & clay) forming micro-sized aggregates. Next step, roots and fungi hyphae bind the micro-sized aggregates to larger forms. The varied charged cations of aluminum, iron, calcium and magnesium bridge the clays with electronic bonds and organic matter continuing to stabilize soil aggregates (Edwards and Bremner, 1967). Newer methodologies are being utilized to identify soil quality characteristics with USDA Natural Resources Conservation Service.

### **What have we learned in rebuilding soil structure?**

- With the overuse of tillage equipment in many farmed fields especially in irrigated fields, farmers believe that plowing is the only way to incorporate organic materials and allow the soil to breathe. Subsequent tillage passes break, smear, crush, squeeze, and pack soils down so they can prepare a seedbed for planting of crops. Each operation is hard on the soil structure, melts when rain or irrigation water is applied, and destabilizes soil structural units.
- Surface soil layers to a depth of 10 to 12 inches that have little or no stable soil structure and poor soil quality are essentially like concrete or as said in soils vernacular – massive or structureless.
- With strip-till or no-till systems, natural soil bio-organisms, fungi, worms, work on prior plant remains slowly breaking down and releasing the polysaccharides and glomalin to form stable soil aggregates and improve soil structure which means better water movement in soils.
- Researchers in eastern Colorado have observed that after two years of reverting back to a multi-pass tillage system compared to no-till, soil porosity decreases by 35-40%.
- With multi-pass tillage systems the soils have little opportunity to allow the natural events of freeze-thaw, organic matter to build up, fungi to survive and organic gums, gels and polysaccharides to glue particles together into block-like forms (macroaggregates) the fundamental structural units of soil.
- Each year growers find their soils do not respond as they would like without plowing to disrupt and explode the structureless matrix and grow a crop.
- When soil is overused and telling us it is damaged it needs a softer touch. In drier periods like that of the past years [2000 – 2004] the improvement in soil quality will be slowed due to lack of soil carbon stored, fewer roots to give off polysaccharides and glomalin gluing agents. In more moist periods scientists and growers have observed marked changes in as little as three years.

#### *For more information:*

Contact your local USDA- Natural Resources Conservation Service office.

Check out <http://www.soils.usda.gov/sqi/>

Here in Colorado contact: Mike Petersen, USDA-NRCS Agronomist at:  
michael.petersen@co.usda.gov

## References:

- Bronick, C.J. and Lal, R. 2005. Soil structure and management: A review. *Geoderma* 124 (1-2):3-22.
- Bending, G.D.; Turner, M.K.; Rayns, F.; Marx, M.C.; Wood, M. 2004. Microbial and biochemical soil quality indicators and their potential for differentiating areas under contrasting agricultural management regimes. *Soil Biology & Microbiology*. 36(11):1785-1792.
- Giri, B.; Mukerji, K. 2004. Mycorrhizal inoculant alleviates salt stress in *Sesbania aegyptiaca* and *Sesbania grandiflora* under field conditions: evidence for reduced sodium and improved magnesium uptake. *Mycorrhiza*. 14(5):307-312.
- Edwards, A.D. and Bremner, J.M., 1967. Microaggregates in soil., *Journ. Soil Science* 18: 64-73.
- Elliott, E.T. and Coleman, D.C., 1988. Let the soil work for us. *Ecol. Bull.* 39:23-32
- Hunt, H.W., Coleman, D.C., Ingham, E.R., Ingham, R.E., Elliott, E.T., Moore, J.C., Rose, S.L., Reid, C.P., and Morley, C.R., 1987. The detrital food web in a shortgrass prairie. *Biol. Fertil. Soils* 3: 57-68.
- Lee, K.E. 1985. Earthworms. Their ecology and relationships with soils and land use. Academic Press, Sydney, Australia.
- Tisdall, J.M. and Oades, J.M., 1982. Organic matter and water-stable aggregates in soils. *Journ. Soil Science* 33:141-163